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Spectrum Efficiency Through Dynamic Spectrum Access Techniques

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Final Report

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Test & Evaluation/ Science & Technology (T&E/S&T)
Spectrum Efficient Technology (SET)

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- Test Resource Management Center \ Spectrum Efficient Technology
- Spectrum Environment Background
- Presidential Memorandum \ Government Agency Responses
- Current Telemetry System Limitations
- Dynamic Spectrum Access Techniques
- Investments in Dynamic Spectrum Access
- Issues
- Summary

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Spectrum Efficient Technology (SET)

Spectrum Efficiency Through Dynamic Spectrum Access Techniques

Tom Young 21 May 2014

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Agenda

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- Spectrum Environment Background
- Presidential Memorandum \ Government Agency Responses
- Current Telemetry System Limitations
- Dynamic Spectrum Access Techniques
- Investments in Dynamic Spectrum Access
- Issues
- Summary

Test Resource Management Center (TRMC)
Sec. 231, FY 2003 National Defense Authorization Act
DoD Directive 5105.71, March 8, 2004

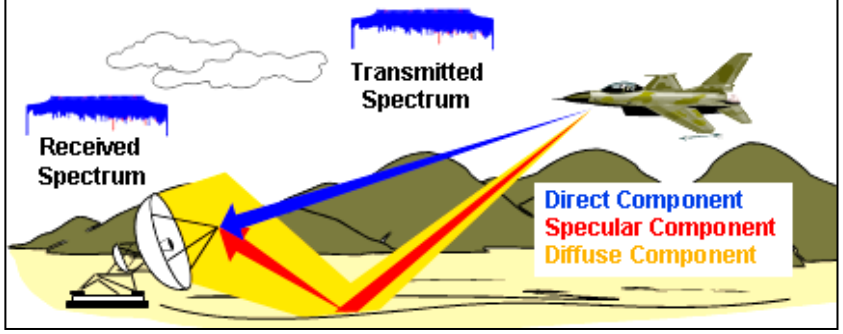
- **DoD Field Activity**
  - Established to ensure that the DoD T&E infrastructure is adequate to support the development and acquisition of defense systems
  - Led by Dr. C. David Brown
    - Direct report to the Honorable Frank Kendall, Under Secretary of Defense (Acquisition Technology and Logistics)
- **Annually certify that the T&E budgets of the military departments and defense agencies are adequate**
- **Develop a biennial strategic plan that**
  - Assesses T&E requirements for a period of ten years
  - Identifies required T&E infrastructure investments
- **Responsible for all T&E infrastructure assessment within the Major Range and Test Facility Base (MRTFB) DoD Directive 3200.11**
- **Administer three major T&E investment programs:**
  - Joint Mission Environment Test Capability Program (JMETC)
  - Central Test and Evaluation Investment Program (CTEIP)
  - *Test and Evaluation/Science and Technology (T&E/S&T) Program*

Spectrum Efficient Technology Mission

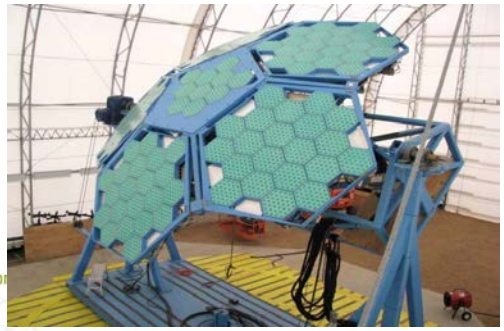
Investigate / mature technologies to optimize the usage of spectrum used for Test and Evaluation

- **Develop new technologies required for test and evaluation to "keep pace" with our evolving military capabilities**
- **Prove innovative alternatives to improve the T&E infrastructure**
- **Current Focus is Telemetry**

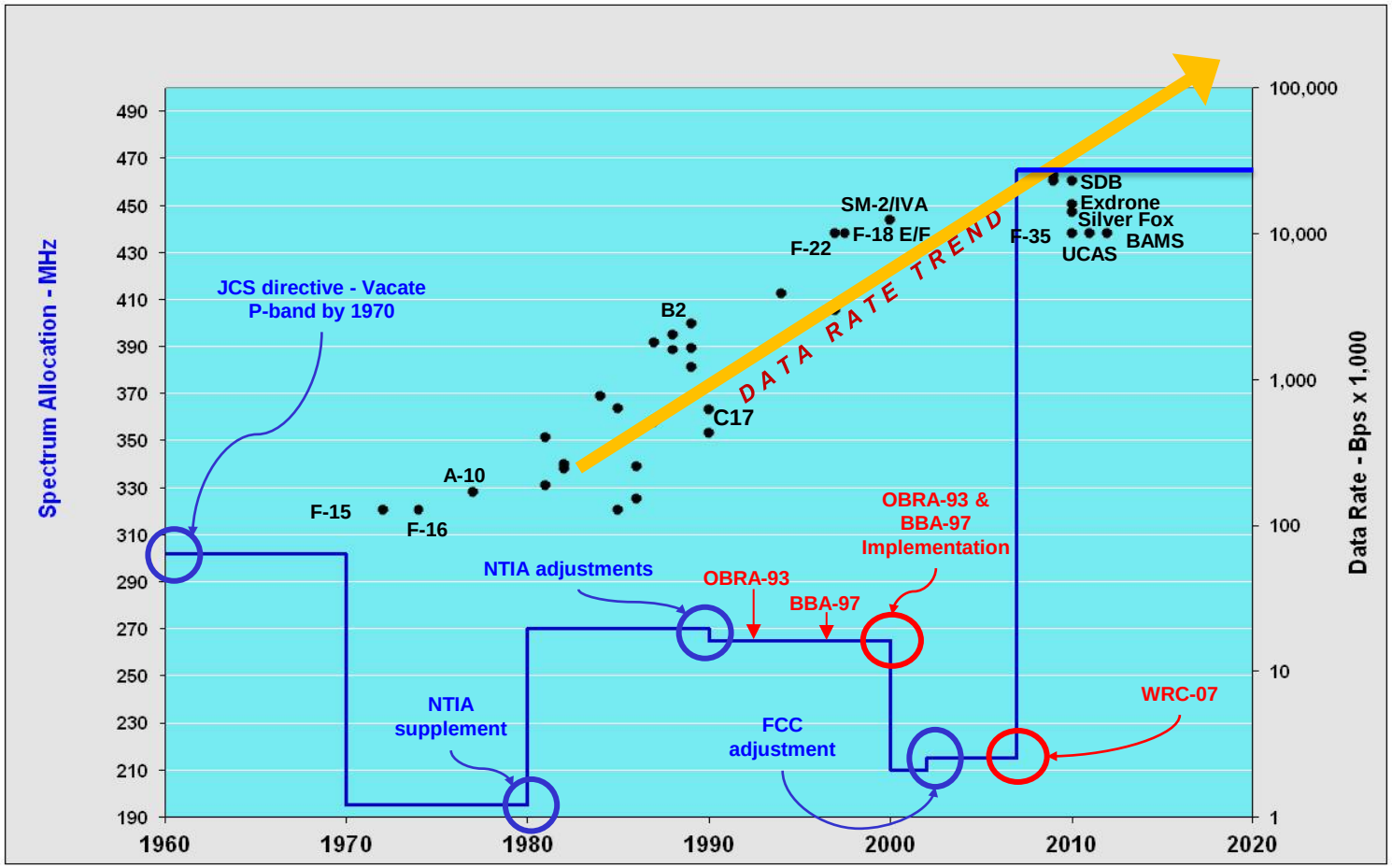
– Legacy telemetry methods are inherently spectrally inefficient



– New data transmission techniques can be applied to wireless Range Data



Data Rate Trends vs. Spectrum Availability



Increased Weapon System Complexity and Reductions in Available RF Spectrum Limit the Amount & Types of T&E Missions a Range can support

T&E RF Spectrum Allocations

- **RF Spectrum allocated to support T&E has decreased substantially (~32%) in Legacy (L- & S-) Bands through previous actions**
  - 325 MHz currently available (includes TSPI)
- **DoD gained access to 1.4 GHz of RF Spectrum in the C-Band via the ITU WRC process**
  - Only 250 MHz of this RF Spectrum is useable to support T&E needs
- **DoD T&E has a documented requirement of 865 MHz by 2025 to support operations**
  - "Spectrum Requirements for Aeronautical Mobile Telemetry: Agenda Item 1.5 WRC-07," Document 8B/143-E, 31 Mar. 2005

575 MHz of Available RF Spectrum Falls Short of Documented DoD TM Requirement of 865 MHz by 2025; Technology Advancements Required to Offset the Difference

Presidential Memorandum

Unleashing of the Wireless Broadband Revolution

THE WHY:

Based on the view that "we are now beginning *the next transformation in information technology*; few technological developments hold as much potential to enhance America's economic competitiveness, create jobs, and improve the quality of our lives as *wireless high-speed access to the Internet*."

ACTION:

Outlines the coordinated efforts within the Federal Government (Secretary of Commerce, Office of Management and Budget, National Telecommunications and Information Administration, Federal Communications Commission, and others) to "identify and make available *500 MHz of spectrum*" to support next generation wireless services.

National Broadband Plan

The FCC's National Broadband Plan sets forth two primary goals and objectives:

1. Affordability of and Accessibility to High Capacity Fixed Broadband

- **By 2015, at least 100 million households should have affordable access to actual download speeds of at least 50 Mbps and actual upload speeds of 20 Mbps**
- **By 2020 at least 100 million households should have such affordable access to actual download speeds of 100 Mbps and actual upload speeds of 50 Mbps.**

2. U.S. Should Lead the World in Mobile Innovation

- **300 MHz of newly available spectrum by 2015**
- **Total of 500 MHz of newly available spectrum by 2020**

WHAT DOESTHIS MEAN FOR T&E?

Target of opportunity-

- **Adjacent channel harmony of existing commercial wireless assets**
- **DoD Test and Training RF resources 1755MHz - 1850MHz Air Mobile Telemetry bands**

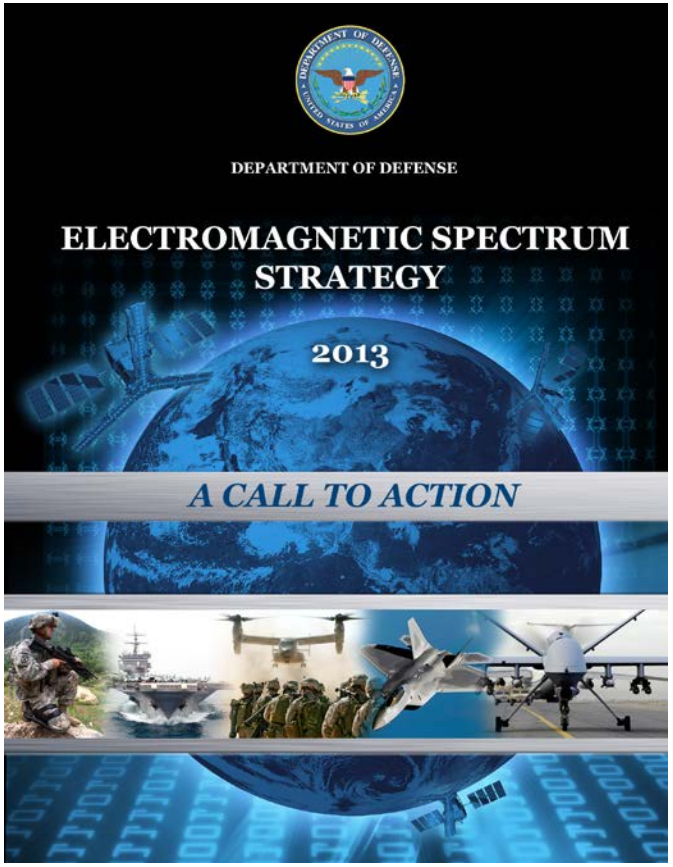
DoD SPECTRUM STRATEGY 2013

VISION: "*Spectrum access when and where needed to achieve mission success*"

Goal 1: Expedite the Development of SDS Capabilities with Increased Spectrum Efficiency, Flexibility, and Adaptability

Goal 2: Increase the Agility of DoD Spectrum Operations

Goal 3: Sharpen the Responsiveness to On-going Spectrum Regulatory and Policy Changes



Current TM System Limitations

- **Airborne Mobile Telemetry mostly unchanged for decades**
  - Incremental improvements e.g. SOQPSK, digital transmitters, improved receivers
- **Point to Point links**
  - Omni antenna(s) on test article(s)
  - Directional high-gain antennas on the ground
  - One way link- “Broadcast”
  - Serial Streaming data; not packetized
- **Frequency allocations are exclusive per system under test**
  - Often frequencies are coordinated over multiple ranges to minimize interference
  - Frequency de-confliction is a manual process
  - Frequencies assignments made prior to mission and are not changed
- **Serial streaming data**
  - Pre-defined static data formats
  - No re-transmission capabilities

Current TM System Limitations

- **Inflexible data formats**
  - Labor intensive to create
  - Typically includes all required data for a major phase of testing (e.g. structural, envelope expansion, avionics, propulsion, etc.)
  - Often includes transmission of unnecessary data for a particular test point during mission execution
- **Dedications of resources**
  - Mechanically tracked directional ground stations can only support one test article at a time
  - High gain ground station antennas used for short range testing
- **Spectrum scheduling and utilization**
  - Manual frequency assignments planned days in advance
  - Frequency excluded from use by others over large geographical areas
  - Little opportunities for frequency re-use
  - Large guard bands between frequencies
  - Slow to adapt to changes in mission execution

Dynamic Spectrum Access (DSA) Enabler

Definition – adaptive techniques that improve a communications system's utilization of the RF spectrum

- **Network Telemetry enables the maximize benefit of DSA**
  - Two-way link key component
  - Re-transmit corrupt data packages
  - Modifying data format during test
  - Health and status of the system under test
  - Requesting data from the on-board recorder not originally telemetered
  - Enables seamless over the horizon coverage

Dynamic Spectrum Access (DSA) Techniques

- **Multiband transmitter/ receivers**
  - Enables flexibility for tuning through allotted DoD TM frequency allocations
- **Transceivers (wireless network)**
  - Enables two-way communication link between test article and ground
  - Enables command & control of onboard assets e.g. recorders, DAUs, transducers
  - Enables dynamic power control
- **Modulation agnostic transceivers**
  - Enables enhanced data quality due to environmental link components e.g. multipath and fading
- **Advanced waveforms**
  - Tier 1-3 enabling more bits per hertz, (pack more data in less RF spectrum)
  - Reduction in guard band requirements
- **Multiple Access Schemes**
  - Enables mobility for handover between networks
  - Provides techniques that allow legacy and network data to cohabitate

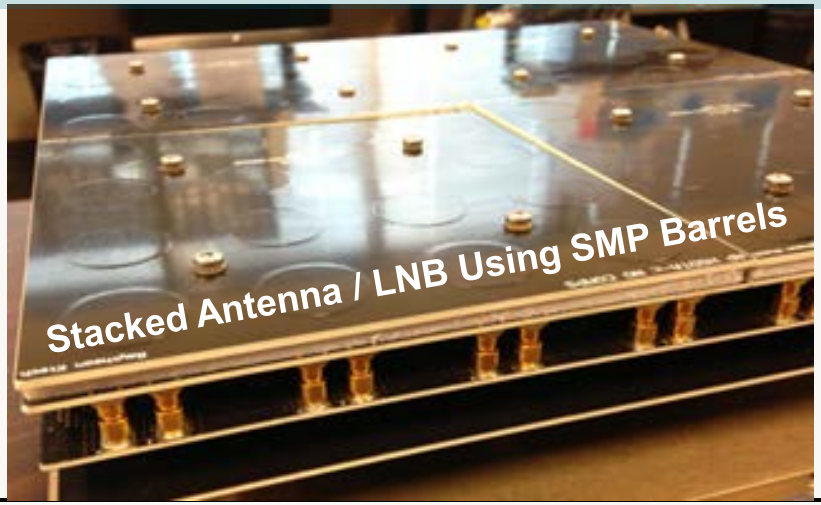
Dynamic Spectrum Access (DSA) Techniques

- **System \ Link management**
  - Enables spectra to be managed like a network resource
  - Move from spectrum to bandwidth scheduling
  - Provides dynamic changes in amount of bandwidth allocated per test article during missions based upon need
  - Enables link characteristics to enhance data connectivity and throughput
- **Steerable phased array test article antennas**
  - Enables frequency re-use
  - Enables greater link availability and data quality

Following charts provide examples of current work that support Dynamic Spectrum Access

SET Domain: Wireless Technologies
Airborne Telemetry Phased Array (AirPA)

Raytheon, Ktech / Albuquerque, NM



Description – AirPA will develop an airborne telemetry phased array antenna and a digital beam-forming controller to improve telemetry collection capability.

Enables: Evaluation of technology maturity to reduce risk for follow on CTEIP effort.

Current Status – Ktech finalized LNB designs, and interface to KAOS; integrated of FPGA code. End-to-end signal path completed. Planning Near-field tests; and demonstration.

Transition Partner / Date: NAVAIR Pt. Mugu / 3QFY14

FY14 Accomplishments

- ✓ Engineering change proposal
- ✓ Conducted Dec PDR; and Antenna Test, TX
- ✓ Raytheon received the AMS hardware

Deliverables (Jun14)

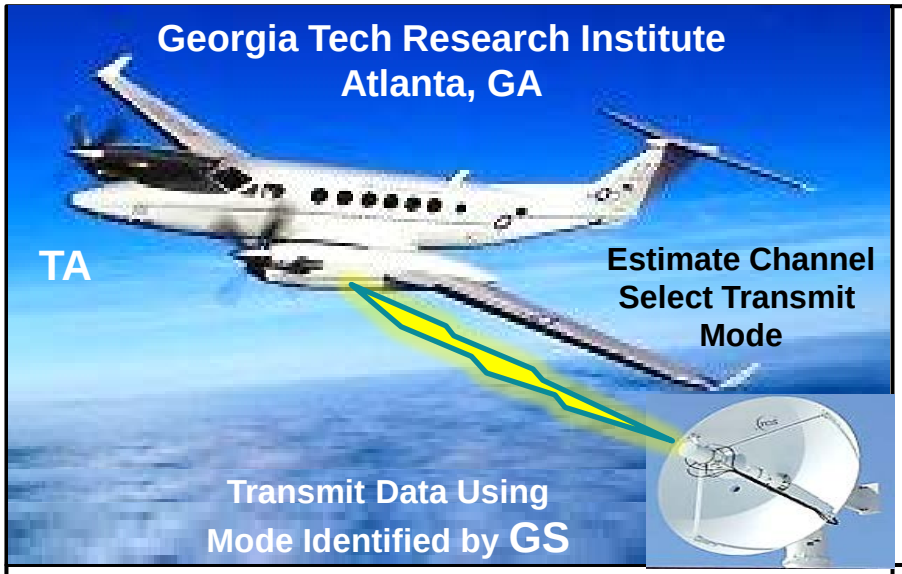
- ❑ Finalized prototype hardware, Final interfaces (software, user), and firmware
- ❑ Phase 3 report and Final project report

Phase/mos.	Mo/Yr	TRL	Status
Ph 1 / 8	**Sep/11**-May/12	4	Completed
Ph 2 / 13	May/12-Jun/13	5	Completed
Ph 3 / 9	Jun/13-**May14**	6	Current
Total			

Key Future Events

- Phase 3 System Near Field Tests, Sudbury, MA
- Phase 3 System Demonstration at Edwards AFB

SET Domain: Wireless Technologies
Link-Dependent Adaptive Radio (LDAR)



Description – LDAR will develop and test a prototype system that adapts its modulation scheme based on environmental channel conditions.

Enables: More efficient communications scheme between test asset and the acquisition site.

Current Status – GTRI finalized LDAR hardware platform; Created LDPC encoder and decoder VIs in LabVIEW; Created SOQPSK modulator and demodulator VIs in LabVIEW. Provided support to MSU.

Transition Partner / Date: iNET / 2QFY16

FY14 Major Accomplishments

✓ Developed simulation tool

Deliverables

✓ Phase 1 Project Execution Plan; Presentation Material; Software; Final Report

❑ Phase 2 Final Report; Software/Firmware; Hardware; Presentation Material

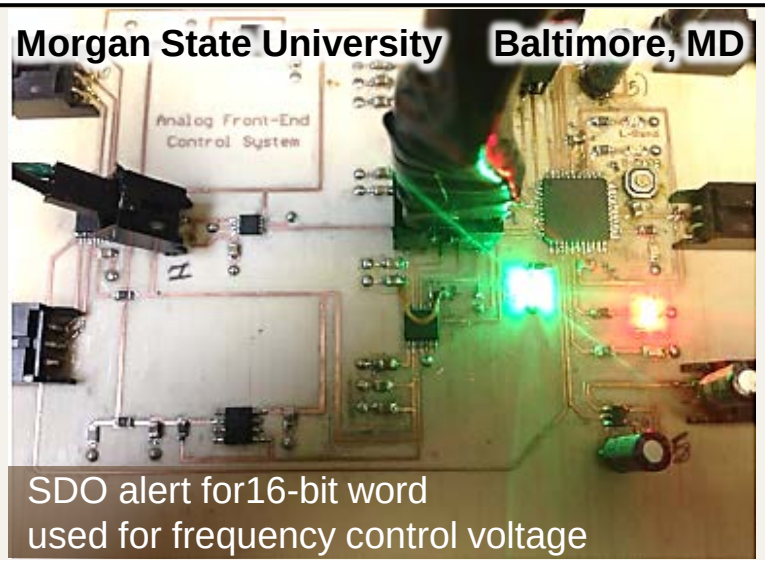
❑ Phase 3 Final Report; Prototype System

Phase/mos.	Mo/Yr	TRL	Status
Ph 1 / 12	**Mar/13**-Mar/14	3	Completed
Ph 2 / 12	Mar/14-Mar/15	4	Current
Ph 3 / 12	Mar/15-**Mar/16**	6	Future
Ph 4 & 5 / 12	Mar/14-**Mar/16**		Current
Total			

Key Future Events

- May 14 Support MSU visit to Edwards
- Jun 14 Design Deep Dive
- Oct 14 Presenting technical papers, ITC, San Diego

SET Domain: Wireless Technologies
Multi-band, Multi-mode Software-Defined Radio (SDR)



SDO alert for16-bit word
used for frequency control voltage

Description – SDR develops a tri-band (L,S,C) transceiver, with several advanced TM waveforms not currently used. Designing and developing a single RF front-end to be integrated with a software defined radio utilizing advanced modulation schemes to form the prototype. Testing will occur at the Air Force Test Center RF Lab.

Enables: Verification of next generation waveform, hardware, and software radio technologies

Current Status – Obtained results of EMI investigation and MBFE Controller prototype.

Transition Partner / Date: AFTC / 4QFY15

FY14 Major Accomplishments

✓ Continued collaboration with LDAR project

Deliverables (Sep14)

✓ Transceiver RF front-end design and prototype

❑ Digital radio framework design & documentation

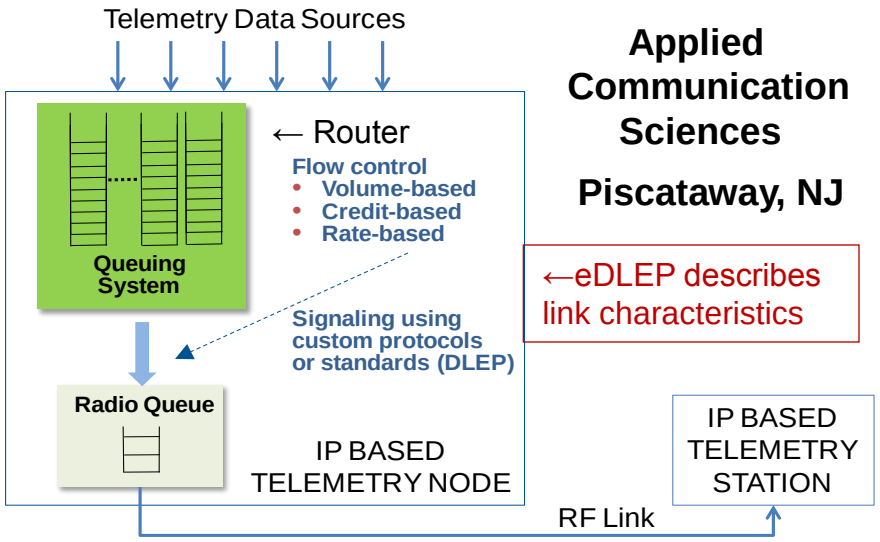
❑ Prototype transceiver.

Phase/mos.	Mo/Yr	TRL	Status
Ph 1 / 12	**Sep/12**-Sep/13	4	Completed
Ph 2 / 15	Sep/13-Dec/14	5	Current
Ph 3 / 9	Sep/14-**Sep/15**	6	Future
Total			

Key Future Events

- Apr 14 CDR Analog Board, and Digital Radio
- Aug 14 C2 CORE SW; Digital Radio; MBFE Board
- Oct 14 Presenting technical papers ITC, San Diego

SET Domain: TM Network
Enhancing Dynamic Link Exchange Protocol for iNET (eDLEP)



Applied Communication Sciences

Piscataway, NJ

←eDLEP describes link characteristics

Description – ACS, with iNET Link Mgr vendor RoboComAI, will develop priority-aligned flow control between the queuing system and the radio for IP-based telemetry systems. Unique features include: Router–radio interface, Fine-grained queue management, and Flow control schemes.
Enables: iNET router/queuing algorithm awareness of the RF channel conditions.
Current Status – ACS implemented an end-to-end prototype. ACS met with NAVAIR to align with iNET, on Phase 1 Test Report and Phase 2 planning.
Transition Partner / Date: iNET / 3QFY16

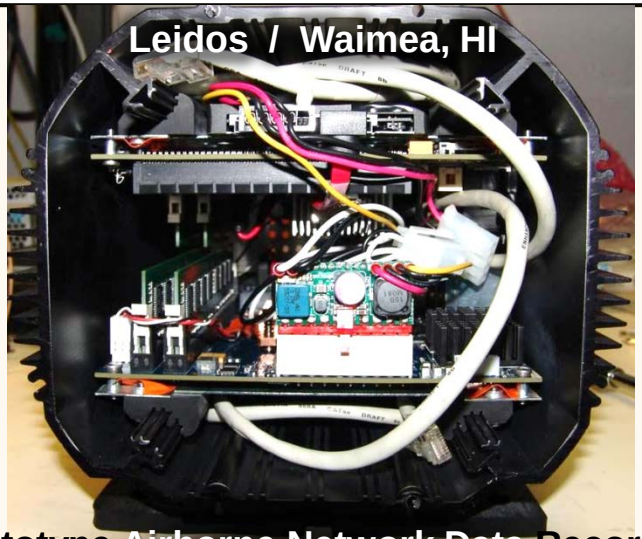
FY14 Major Accomplishments
- ✓ Developed initial eDLEP protocol prototype
- ✓ Developed System Design and Software Guide

Deliverables (Mar14)
- ✓ System requirements and architecture report; System design report
- ❑ Software source code; Software documentation and test report
- ❑ Phase final report

Phase/mos.	Mo/Yr	TRL	Status
Ph 1 / 12	**Mar/13**-Mar/14	4	Completed
Ph 2 / 12	Mar/14-Mar/15	5	Current
Ph 3 / 12	Mar/15-**Mar/16**	6	Future
Total			

Key Future Events
- Design capacity allocation algorithms
- Oct 14 Presenting a technical paper at ITC, San Diego

SET Domain: TM Network
Enhanced Query Data Recorder (EQDR)



Prototype Airborne Network Data Recorder

Description – EQDR will develop, integrate and demonstrate a spectrum efficient network recorder to support the Integrated Enhanced Network Telemetry (iNET) program.

Enables: Validates iNET prototype system components.

Current Status – Preparing for Phase 3/ Smart Sensor flight demonstration at Edwards AFB. Enhanced EQDR iNET interface.

Transition Partner / Date: iNET / 3QFY13

FY14 Major Accomplishments

- ✓ Presented technical paper at ITC
- ✓ Delivered Phase 3 prototype.

Deliverables (Aug14)

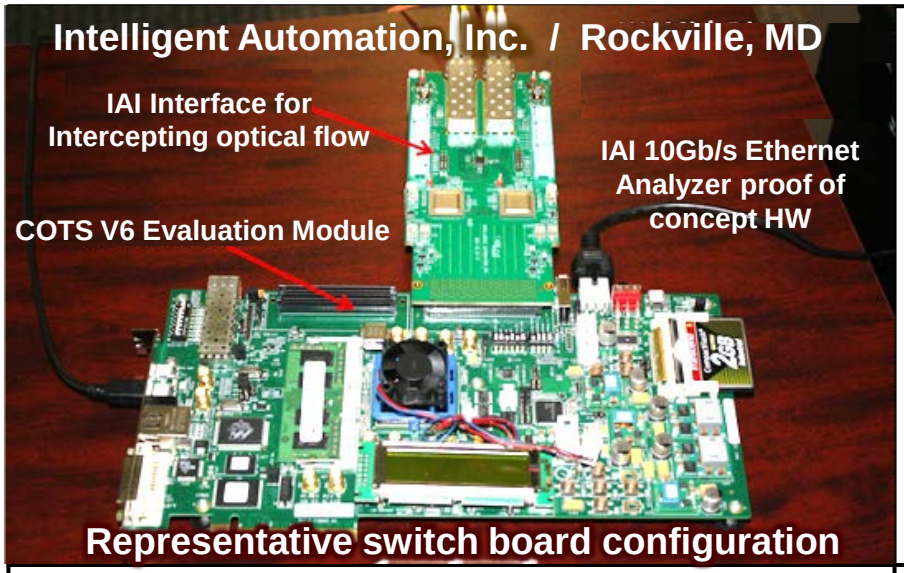
- ❑ Hardware / software, and Database Management System (DBMS)
- ❑ Source Code EQDR

Phase/mos.	Mo/Yr	TRL	Status
Ph 1 / 6	**Aug/11**-Feb/12	4	Completed
Ph 2 / 19	Feb/12-Sep/13	5	Completed
Ph 3 / 24	Aug/12-**Aug/14**	6	Current
Total			

Key Future Events

- Aug 14 Smart Sensor Flight Demonstration, Edwards AFB
- Oct 14 ITC, San Diego

SET Domain: TM Network
Non-Blocking Layer 2/3 Ruggedized Ethernet Switch (NRES)



Description – Produces a novel 16 port layer 2/3 ruggedized Ethernet switch for airborne systems that guarantees non-blocking functionality for 16 ports at speeds up to 10Gbps per port in real time. Includes an FPGA chip with a vast resources and processing power.

Enables: Key component of next generation iNET test article network.

Current Status – IAI is designing the configuration Graphical User Interface (GUI) and has developed support for Simple Network Mgmt. Protocol (SNMP).

Transition Partner / Date: iNET / 2QFY15

FY14 Major Accomplishments

✓ Delivered initial draft requirements document

Deliverables (Mar14)

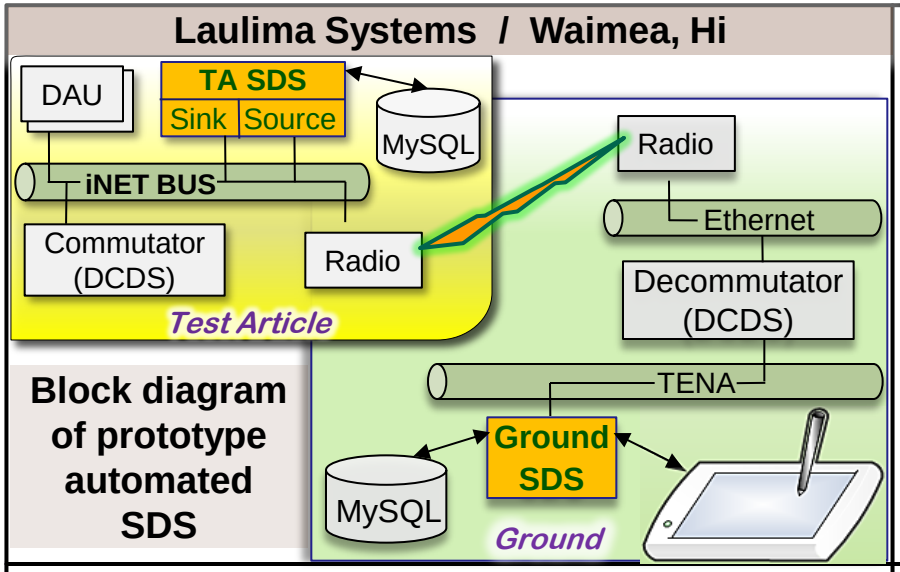
❑ Prototype switch, demonstration and validation in iNET Systems Integration Lab (SIL)

Phase/ mos.	Mo/Yr	TRL	Status
Ph 1 / 9	**Mar/13**-Dec/13	3	Completed
Ph 2 / 12	Jan/14-**Dec/14**	6	Current
Total			

Key Future Events

- Delivery of the final NRES Engineering Design Document
- Functional/Stress testing of NRES.

SET Domain: TM Network Smart Data Selection (SDS)



Block diagram of prototype automated SDS

Description – Develop an SDS capability that continually monitors and selects which real-time test data to send to the ground. SDS augments current approaches to TM, and sets up more spectrum efficiency by sending actionable information/sec/Hz to ground.
Enables: Selection of data based upon real-time events.
Current Status – Developing Final Report. Completed ECP regarding new TM protocol.
Transition Partner / Date: AFTC / 1QFY14

FY14 Major Accomplishments

✓ Presented technical paper at ITC

Deliverables (Nov13)

✓ System Requirements Document

❑ Smart Data Selection Software

❑ Demonstration Hardware

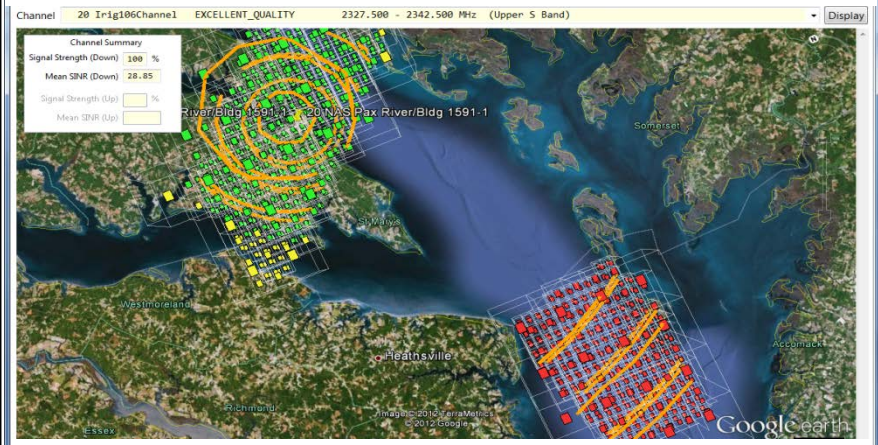
Phase/ mos.	Mo/Yr	TRL	Status
Ph 1a / 13	**Mar/13**-Apr/14	3-6	Completed
Ph 1b / 6	Apr/14-**Oct/14**	6	Current
Total			

Key Future Events

- TBD CY14 SDS Demonstration
- 7 Oct 14 Project completion

SET Domain: Spectrum Management Spectrum Management System With Channel Modeling and Improved Coding Techniques (SMS)

Applied Communication Sciences/ Piscataway, NJ



Terrain map GUI with Freq re-use areas shown

Description - SMS will develop a platform for optimized frequency planning to increase utilization of the RF bandwidth for flight test telemetry. Efficiency realized through frequency re-use planning algorithms for telemetry networks and legacy telemetry systems.

Current Status – Project completion 31 Jan 13

Transition Partner

PAX, WSMR

FY13 Accomplishments

- ✓ Transition Meeting at PAX with Frequency Management and Range Engineering
- ✓ Phase 3 Task 2 (SMS Transition)
- ✓ Rack-And-Stack algorithm design

Deliverables (Dec12)

- ✓ Report on Spectrum Efficiency Improvements
- ✓ SMS Prototype software updated with Phase 3 enhancements; plus accompanying documents

Phase/ mos.	Mo/Yr	TRL	Status
Ph 1 / 12	**Apr/10**-Mar/11	4	Completed
Ph 2 / 10	Apr/11-Jan/12	5	Completed
Ph 3 / 10	Feb/12-**Dec/12**	6	Completed

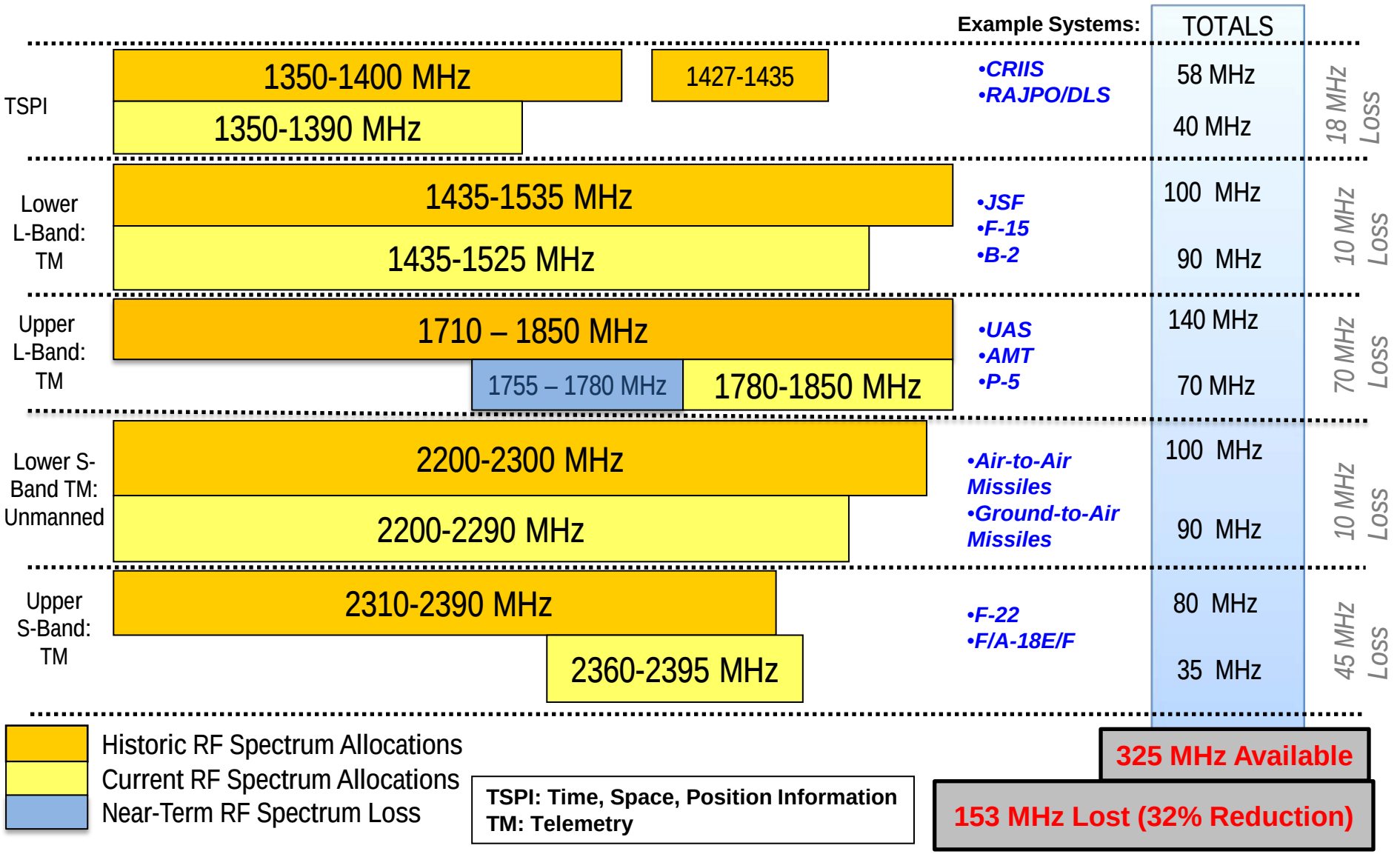
- 31 Jan 13 Project closed out

Summary

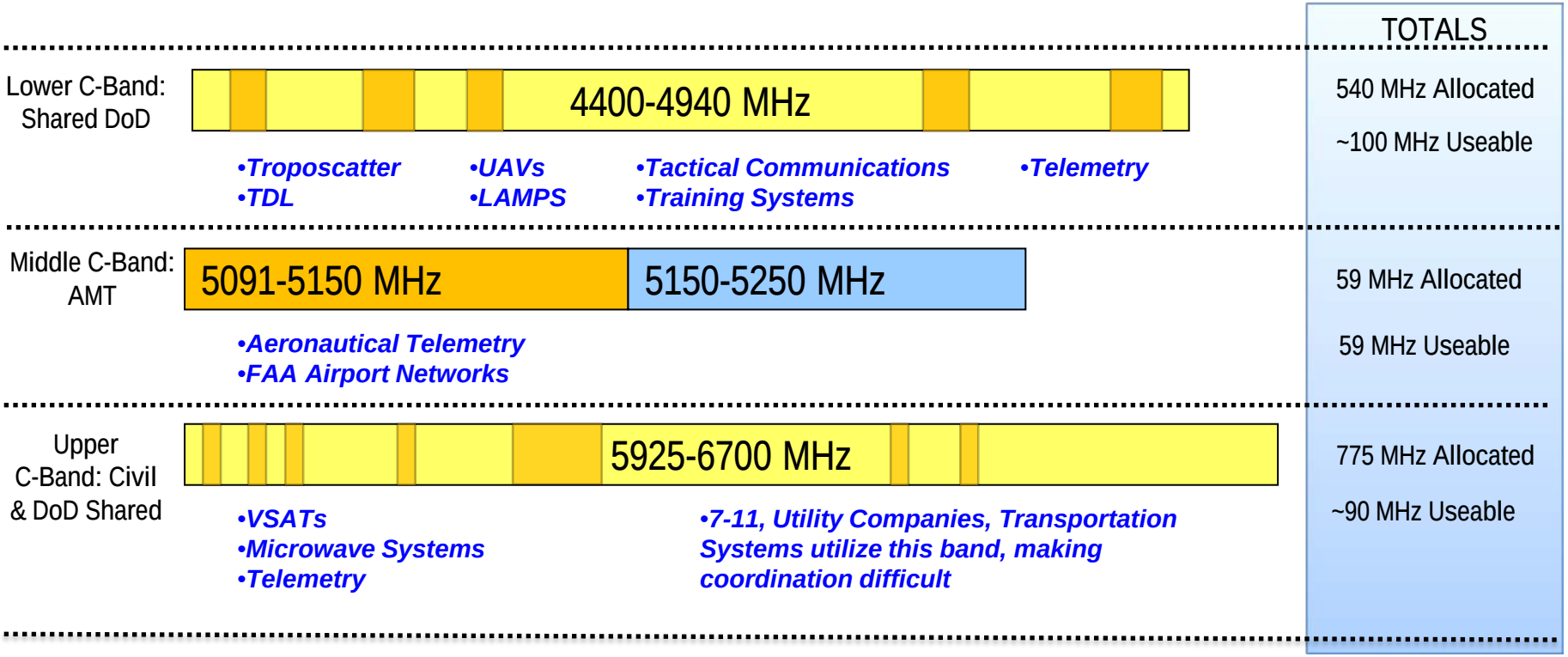
- S&T applied research funded by OSD TRMC
- Why dynamic access to spectrum is required
- Additional encroachment that will impact the DoD RF allocations
- Current Limitations that the Ranges face
- Techniques that use spectrum dynamically to meet the test need
- Some examples of current investment in Dynamic Spectrum Access

Backups

T&E RF Spectrum Allocations



T&E RF Spectrum Allocations



Current RF Spectrum Allocations
Useable RF Spectrum: Location Dependent
Desired RF Spectrum Allocation*

~250 MHz Useable Spectrum

LAMPS: Light Airborne Multi-Purpose System
TDL: Tactical Data Link
VSATs: Very Small Aperture Transmissions
UAV: Unmanned Aerial Vehicle

***DoD not currently authorized to operate in 5150-5250 MHz; Desire access to band to offset Spectrum Reallocation activities/losses**